Polish Society of Composite Materials
Polskie Towarzystwo Materiałów Kompozytowych

14: 2 (2014) 101-105

COMPOSITES THEORY AND PRACTICE

Anita Olszówka-Myalska[1]* Jerzy Myalski[1], Konrad Wrzała[2]

[1] *Silesian University of Technology, Department of Materials Science, ul. Krasińskiego 8, 40-019 Katowice, Poland*
[2] *SILUM sp. z o.o. Opojowice 51, 98-310 Czarnożyły*
**Corresponding author. E-mail: anita.olszowka-myalska@polsl.pl*

Received (Otrzymano) 24.03.2014

FABRICATION OF MAGNESIUM MATRIX COMPOSITE WITH GLASSY CARBON PARTICLES BY PRESSURE DIE CASTING

The preliminary results on the application of cold chamber pressure die casting for fabricating a magnesium matrix composite with glassy carbon particles were presented. For small-sized composite casts, processing a suspension obtained by remelting of composite ingots was applied. Those ingots were previous fabricated by mechanical stirring and gravity casting. Composite casts of a mass of 14 g, complex shape and homogenous particles distribution, without cast defects were obtained. Their macrostructure, microstructure and mechanical properties were characterized. The usefulness of pressure casting for the fabrication of particulate magnesium matrix composite casts was revealed.

Keywords: **magnesium matrix composite, composite casts, glassy carbon particles, pressure die casting**

WYTWARZANIE METODĄ ODLEWANIA CIŚNIENIOWEGO KOMPOZYTU Z OSNOWĄ MAGNEZOWĄ I CZĄSTKAMI WĘGLA SZKLISTEGO

Zaprezentowano wyniki wstępnych prac nad zastosowaniem odlewania ciśnieniowego kompozytu z osnową magnezową i cząstkami węgla szklistego. Do odlania małogabarytowych odlewów kompozytowych wykorzystano suspensję powstałą w wyniku przetopu wtórnego półproduktów w postaci wlewków kompozytowych wytworzonych metodą mechanicznego mieszania i odlewania grawitacyjnego. Otrzymano odlewy kompozytowe ciśnieniowe z osnową ze stopu Mg3Al, zawierające 13% objętościowych cząstek o średniej granulacji 150 µm, rozmieszczonych równomiernie w osnowie. Masa pojedynczego wyrobu odlewanego o złożonym kształcie wynosiła 14 g. Scharakteryzowano makrostrukturę, mikrostrukturę i właściwości mechaniczne odlewów. Nie stwierdzono destrukcyjnych efektów obecności hydrofilowego węglika Al_4C_3. Przeprowadzone próby technologiczne potwierdziły przydatność wykorzystania odlewania ciśnieniowego do otrzymywania małogabarytowych odlewów z kompozytów z osnową magnezową.

Słowa kluczowe: **kompozyty z osnową magnezową, odlewy kompozytowe, węgiel szklisty, odlewanie ciśnieniowe**

INTRODUCTION

Powder metallurgy processes may be applying in the fabrication of particulate light metal matrix composites and those processes are also very convenient in laboratory research to develop component composition, volume fracture and size of the reinforcing phases as well as characterization of the processes occurring at the interface. Because both the size and shape of composite products obtained by PM technology are limited, casting technologies seem to be more perspective in metal matrix composite manufacturing. However, their real potential must be first experimentally verified for each component system because the effects occurring in a suspension of liquid metal with solid reinforcing phases are more complex than in metal alloys.

In the paper, pressure die casting was tested for a new type of composite where magnesium as the matrix and glassy carbon as the particulate phase were used, because by that method the fabrication of a large quantity of small to medium sized castings of magnesium is successfully performed [1-3].

The application of glassy carbon particles (GCp) in magnesium matrix composites arose from their high hardness 260 HV and density slightly less than magnesium alloys. Previously, improvement of the wear resistance and stiffness as a result of GCp implementation in magnesium alloys was revealed for our fabricated composite on a laboratory scale by hot pressing of a metal-particles powder mixture in vacuum [4].

In the carried out experiments, a suspension of Mg alloy-GCp prepared from remelted ingots of the composite previously fabricated by stirring and gravity casting was applied. Small-sized composite casts of complex shape were manufactured by pressure die casting and then their macrostructure, microstructure and mechanical properties were characterized.

TECHNOLOGICAL PROCEDURE

For cold chamber pressure die casting, composite ingots of magnesium alloy Mg3Al (Al 3.5 wt.%) and GCp particles of a mean granulation of 150 μm, and hardness of 33.3±1.7 HB were used as the batch material. The ingots were obtained in industrial conditions by stirring and gravity casting from a temperature of 680°C. At first, the ingots surface was cleaned by abrasive machining (Fig. 1) and heated 1 hour up to 680°C in the protective gas atmosphere of a CO_2 and SF_6 mixture. Then the obtained composite suspension was homogenized by mechanical stirring with a steel stirrer coated with a ceramic protective layer, and after that the suspension was ready for pouring with a ladle into a 250 T pressure die casting machine. That procedure was precisely described in [5].

Fig. 1. Composite ingots cleaned by abrasive machining applied for preparation of secondary suspension

Rys. 1. Wlewki kompozytowe oczyszczone abrazyjnie, zastosowane do otrzymania suspensji wtórnej

In the presented experiments, two different steel dies were used: for samples for mechanical properties characterization and for final composite products manufacturing. A view of the fabricated casts removed from the pressure casting machine is presented in Figure 2.

Then the trimming procedure on a press completed with a proper trimming tool was carried out to obtain the final composite products of a mass of 14 g each and a size of 52x19x9 mm (Fig. 3). It was visible that the fabricated casts imaged the surface of the applied steel dies properly, their surface was smooth and without macrospopic defects. The macro-observations of a cross-sectioned composite cast (Fig. 4) showed the effect of particles pulled out during cutting and polishing in some microareas, and the presence of a few single and very small pores located far from the cast edges. That suggests good quality of the obtained composite products.

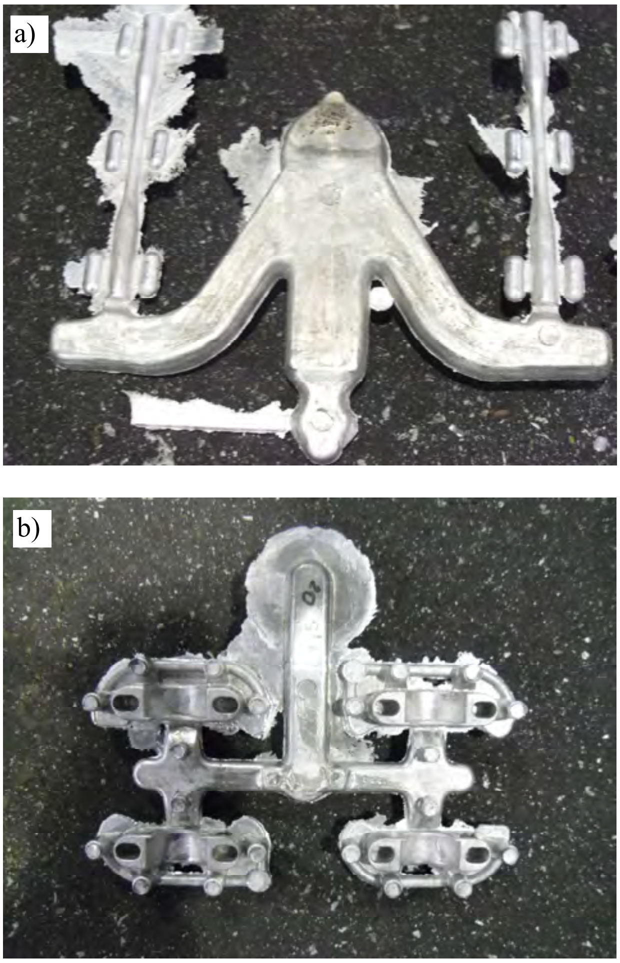

Fig. 2. Composite casts after removal from pressure die cast machine: a) samples for mechanical properties examination, b) composite products

Rys. 2. Odlewy kompozytowe po wyjęciu z ciśnieniowej maszyny odlewniczej: a) próbki do badań właściwości mechanicznych, b) wyroby kompozytowe

Fig. 3. Macrograph of Mg3Al-GCp composite casts after trimming procedure

Rys. 3. Makrofotografia wyrobów odlanych z kompozytu Mg3Al-GCp po okrojeniu na prasie

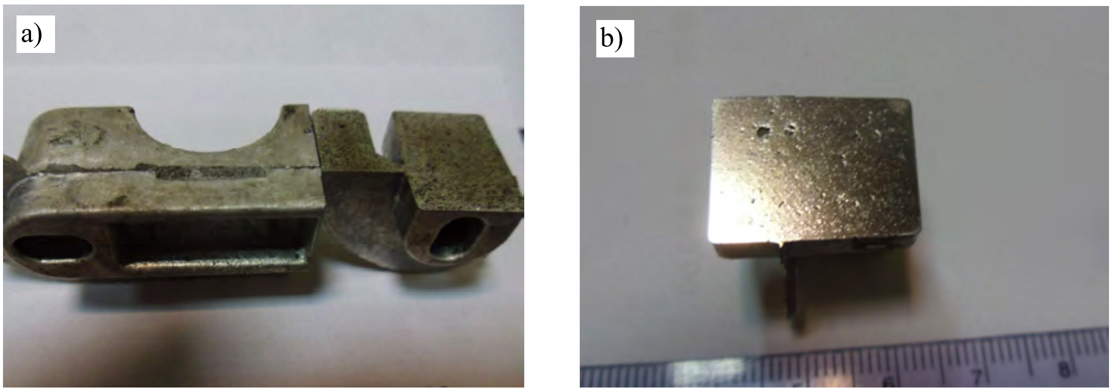

Fig. 4. Macrographs of cross-sectioned composite cast: a) after cutting, b) after polishing

Rys. 4. Makrofotografia przekroju poprzecznego odlewu kompozytowego: a) po przecięciu, b) po wypolerowaniu

MICROSTRUCTURE AND PROPERTIES

Microstructure characterization was carried out on the composite samples in the form of a polished cross-section and fractured cross-section using the scanning electron microscopy method (FE-SEM Hitachi 3200S) with energy dispersive spectroscopy (EDS). A homogenous particles distribution without clusters and proper connection with the matrix were visible in the micrographs of the polished cross-section (Fig. 5a), and were confirmed by fractured cross-section examination (Fig. 5b). Cracking and decohesion of the particles during tensile testing were revealed as well as fracturing at the particle-matrix interface (Fig. 5b, c). In spite of the presence of Al in the applied magnesium alloy, the effect of GCp degradation as a result of their interaction with the liquid matrix alloy and hydrophilic phases formation was not registered during sample preparation or their microstructure observation.

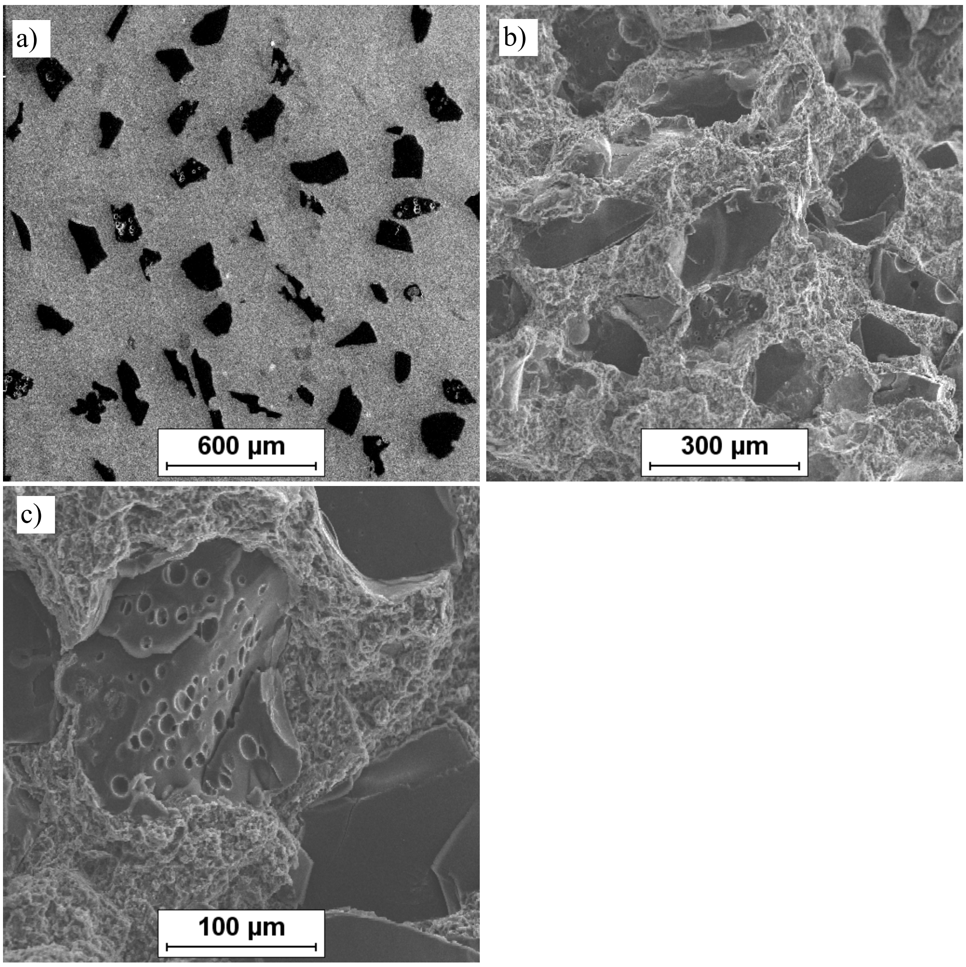

Fig. 5. Micrographs of Mg3Al-GCp composite: a) polished cross-section, b, c) fractured cross-section after tensile test SEM

Rys. 5. Mikrofotografie kompozytu Mg3Al-GCp: a) zgład, b, c) przełom po próbie rozciągania

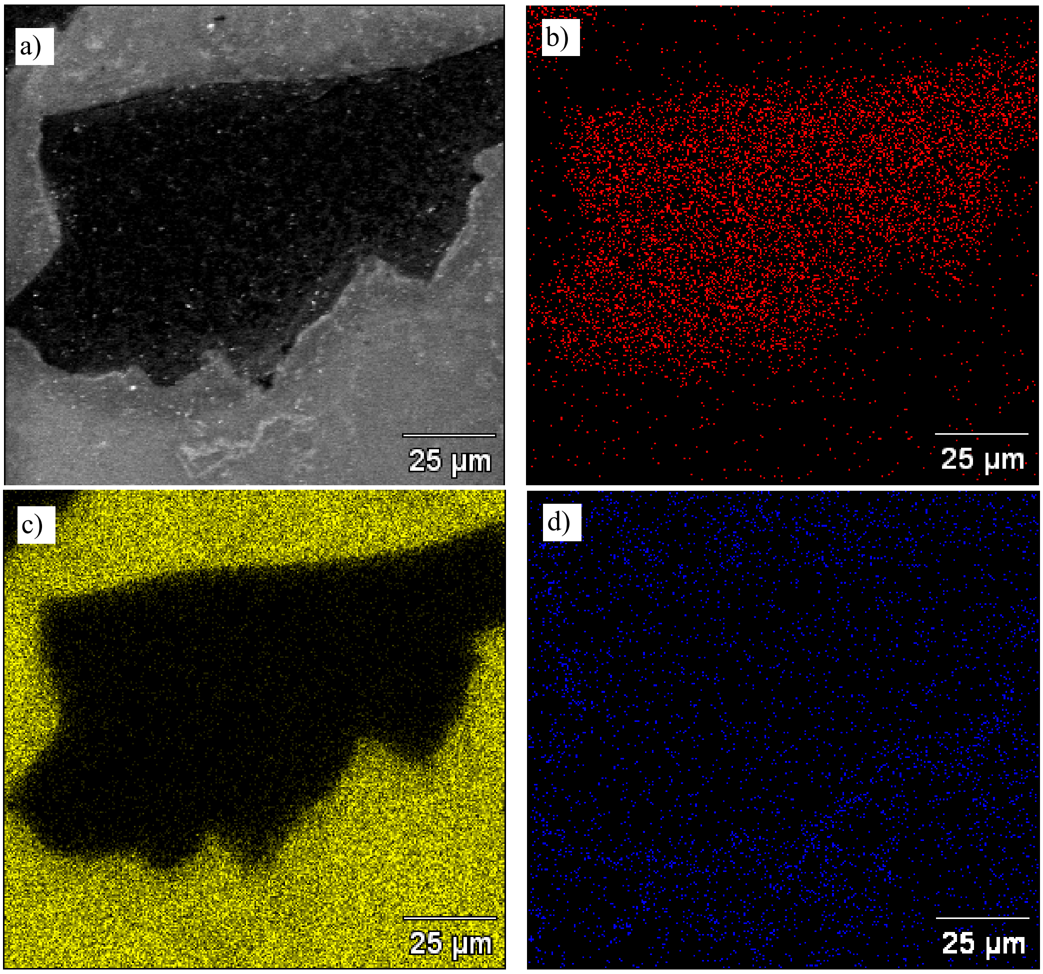

Fig. 6. Results of EDS examination: a) SEM image, b-d) mapping of C, Mg and Al respectively

Rys. 6. Wyniki badań EDS: a) obraz SEM, b-d) rozkłady powierzchniowe rentgenowskiego promieniowania charakterystycznego C, Mg i Al

The quantitative characteristic of the obtained composite microstructure was performed using the Metilo program. The volume fraction of glassy carbon particles in the composite was determined to be 13%, and the parameters of their plane section obtained on the basis of 450 measured particles in Table 2 were specified. The obtained values of the stereological parameters showed that the applied GCp were homogenous in size and in a polyhedronal shape.

TABLE 1. **Stereological parameters of GCp in obtained Mg3Al-GCp composite cast**

TABELA 1. **Parametry stereologiczne cząstek węgla szklistego w otrzymanym odlewie kompozytowym Mg3Al-GCp**

Parameter	Mean value	Coefficient of variation [%]
Plane section area [μm^2]	8350.3	77.2
Perimeter [μm]	372.2	52.7
Shape factor	0.68	25.5
Elongation	1.94	34.5
Equivalent diameter [μm]	92.9	48.1
Normalized area	0.21	77.2

The results of the tensile strength and HB hardness examination of the pressure die casted composite are presented in Table 2. A simple comparison of the fabricated composite properties with commercial magnesium materials is difficult. Due to the preliminary nature of the carried out experiments, a synthetic Mg3Al alloy instead of a commercial magnesium alloy was applied because at this step of the investigation, the problem of Al_4C_3 phase formation as a product of liquid metal-carbon interaction was also analyzed. The obtained values of *Rm* and *E* for the pressure die casted composite are higher than for pure magnesium but at the level of some magnesium alloys only, while the plasticity (A) is rather slight. The tensile test examination of the semi-product applied as the material for the secondary suspension preparation was not possible because all the samples of that material were cast at a temperature of 680°C to decrease the carbon-alloy reactivity. At that temperature, the castability of the suspension was low and the samples for the tensile test which were poured into ceramic moulds were defective. Therefore, comparison of the hardness was possible only. A significant hardness increase was observed, from 33 HB for a gravity cast composite up to 68 HB for a pressure die cast, and that result confirmed the usefulness of the applied technological procedure.

TABLE 2. **Mechanical properties of Mg3Al-GCp pressure diecasted composite**
TABELA 2. **Właściwości mechaniczne odlanego ciśnieniowo kompozytu Mg3Al-GCp**

Rm [MPa]	E [GPa]	A [%]	Hardness HB
135±20	16.7±0.89	2.4±1	67.5±1.8

SUMMARY

The preliminary results of the application of pressure die casting technology were presented for a magnesium matrix composite with glassy carbon particles. The usefulness of composite ingots as a semi-product for the preparation of a composite suspension in pressure die casting was revealed. The possibility of fabricating small-sized composite casts with a complex shape by pressure die casting technology, similar to commercial alloys of light metals was shown. The applied parameters of the technological procedure ensured a homogenous material with a 13% particles content and without destructive structural effects at the carbon/Mg3Al alloy interface. A significant hardness increase of the composite after pressure casting was observed in comparison with that material after stir casting. Because the mechanical properties of the composite were not satisfying comparing with the best commercial magnesium alloys, in further experiments modification of the magnesium matrix composition is recommended.

Acknowledgement

This work was supported by the Ministry of Science and Higher Education of Poland (project N Nr 15-0077-10/2010).

REFERENCES

[1] Mordike B.L., Ebert T., Magnesium properties - applications - potential, Materials Science and Engineering 2001, A302, 37-45.

[2] Gupta M. et al., Magnesium, Magnesium Alloys and Magnesium Composites, John Wiley and Sons, 2010.

[3] Lee B.D., Baek U.H., Han J.W. Optimization of gating system design for die casting of thin magnesium alloy-based multi-cavity LCD housings, Journal of Materials Engineering and Performance 2007, 17, 1, DOI: 10.1007/s11665-011-0111-1.

[4] Olszówka-Myalska A., Myalski J., Botor-Probierz A., Microstructural characteristics of an AZ91 matrix-glassy carbon particle composite, Advanced Engineering Materials 2010, 12, 7, 609-616.

[5] Sposób wytwarzania odlewów ciśnieniowych z wlewków z kompozytu z osnową z magnezu lub stopów magnezu i zdyspergowanymi komponentami węglowymi (UP RP nr. P. 406195 dn. 22.11.2013).

